account for both phenomena. In practice, this is not quite so serious an indictment of previous work as it may appear, for it happens that some of the explanations proposed for one phenomenon automatically take account of the other. This is particularly true for the most favoured explanation for the low velocity—partial melting—which also implies high attenuation. On the other hand, the need for a dual explanation does rule out certain other proposed effects, such as scattering, dislocation damping and thermoelasticity. After rejecting some other (including dual) models on various grounds, Gueguen and Mercier conclude that, of previously proposed explanations, only partial melting or the presence of viscous grain boundaries can adequately explain the two chief features of the LVHAZ.

But they also examine in detail a third possibility — dislocation-impurity interactions—which, though apparently not considered much before, is in their view as likely as the other two. Certainly the presence of dislocations (either inside grains or at grain boundaries) together with impurities can be shown to be related to attenuation. For example, Jackson (*Grain Boundary Relaxation and the Attenuation of Seismic Waves*, thesis, MIT, Cambridge, 1969) demonstrated that, at temperatures near the melting point, a rapid increase in attenuation occurs in polycrystals and in previously deformed single crystals and that this attenuation depends on the nature of the impurities present. Moreover, Chang (*J. app. Phys.*, **32**, 1127; 1961) observed an impurity-dependent relaxation peak in both single crystals and polycrystals of Al_2O_3 at temperatures of about half the melting point.

Gueguen and Mercier now show formally that the experimental data obtained by Chang and Jackson are consistent with a model in which dislocations interact with point defects. Moreover, they also show that this mechanism can lead to a seismic velocity decrease and an attenuation at least as great as those actually observed.

On the face of it, there is still little reason to discard the idea of partial melting, although by the same token there may be no case for particularly favouring it over the other two explanations. Of course, part of the independent support for partial melting comes from the occurrence of volcanism; but as Gueguen and Mercier point out, there need not necessarily be any connexion between a partially molten LVHAZ and magma appearing at the Earth's surface. Near-surface melting could be produced by, for example, adiabatic decompression of material undergoing upward transport, thereby resulting in fusion. Moreover, partial melting is not the only mechanism capable of producing a plastic zone susceptible to flow, for dislocations are also known to induce plastic behaviour.

But there is even more to it than that. Ironically, the expression for viscosity obtained by Gueguen and Mercier on the basis of dislocation-impurity theory is formally identical to that obtained by Walsh (*J. geophys. Res.*, **73**, 4333; 1969) in the basis of partial melting theory. The reason for this is apparently that grain boundaries are neither liquid nor solid but an intermediate state, so that Walsh's approach using a viscous (liquid-state) phase between grains and the Gueguen–Mercier approach regarding boundaries as an array of dislocations in a solid are, under certain circumstances, equally valid approximations to the real situation. What this means is that it is not possible to use seismic data alone to distinguish between the partial melting attenuation model and the dislocation-point defect interaction attenuation model.

LOW TEMPERATURE PHYSICS

Ions in Liquid ^{3}He

from a Correspondent

A NOVEL technique for measuring the mobility of ions in liquid ^{3}He has been devised by P. V. E. McClintock of the University of Lancaster (*J. low Temp. Phys.*, **11**, 277; 1973), which has important implications for future ion experiments in the mK temperature range.

Like the common isotope ^{4}He, liquid ^{3}He displays exotic properties at very low temperatures but, unlike the case of ^{4}He, these properties do not manifest themselves suddenly on the low temperature side of a phase transition. Rather, there is a gradual change from classical behaviour above 2 K to a regime where the behaviour is completely dominated by quantum statistics below a few tenths of a Kelvin. Because ^{3}He is a fermion, and therefore subject to the restriction that only a single particle is allowed to occupy one quantum state, whereas ^{4}He is a boson, for which multiple occupancy is permitted, the low temperature properties of the two liquids are completely different.

One way in which liquid ^{3}He differs from ^{4}He is that, far from becoming superfluid (except, perhaps, under high pressure near 2 mK), its viscosity actually increases with falling temperature. This can be understood in that nearly all the low-lying energy states will be occupied, up to some maximum energy ϵ_F, known as the Fermi energy, near which lie the only accessible empty states. Thus, the only atoms whose states can easily be changed will be those with energies close to ϵ_F. Because, as the temperature is reduced, there are progressively fewer states into which they can be scattered, the difficulty encountered in changing the liquid's macroscopic configuration, that is, the viscosity, will increase, in agreement with experiment.

Much information on the nature of both the liquid isotopes has been gained from studying the motion of ions, and one quantity which is of interest is the mobility μ, that is the ion's equilibrium drift velocity divided by the electric field causing it to move. In the case of ^{3}He, the progressive depletion with falling temperature of the number of empty states near ϵ_F into which an atom can be scattered means the probability that an ion will be able to interact with any particular atom which it encounters is going to decrease, so that μ should increase with falling temperature.

The theoretical conclusion, therefore, is that the viscosity and charge mobility should both increase with falling temperature, that is the "thicker" the liquid becomes the more easily the ions should slip through it.

Early attempts to measure mobilities in ^{3}He ran into difficulties arising partly from the type of ion source which was used. A. C. Anderson, M. Kuchnir and J. C. Wheatley, then of the University of Illinois (*Phys. Rev.*, **168**, 261; 1968). used a radioactive source to generate the ions, and the thermal gradient set up in the liquid by radioactive heating at this source seems to have been, in part, responsible for a very large scatter in their measurements. It did appear, however, that the positive ion mobility was indeed increasing with falling temperature, although much more slowly than had been predicted.

A novel feature of the technique developed by McClintock lies in the use of a field-emission ionization ion source consisting, basically, of an exceedingly sharp tungsten point which, raised to a potential of a few kilovolts, is able to inject ions of either sign into the liquid. The great merit of this source is that it can be pulsed, and so generates heat only when it is actually running, unlike radioactive sources which heat the liquid continuously. The measurements show very much less scatter than those of the Illinois group, and have enabled a hitherto unsuspected minimum in μ, possibly representing the transition from classical to quantum behaviour, to be resolved.

It is particularly desirable that the experiments be extended to the region below 10 mK, for which some rather bizarre behaviour has been predicted by R. M. Bowley of Nottingham University (*J. Phys.*, C4, L207; 1970). He believes that there is a regime in which, for any given electric field, the mobility will be treble-valued, that is an ion will have three, equally valid, equilibrium drift velocities to choose from. Experiments based on this source should enable this prediction to be tested.